Project of Strategic Interest NEXTDATA

Scientific Report for the reference period 01/01/2013 – 31/12/2013

WP 1.4 Environment and climate data from non-polar ice cores

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1. Scheduled activities, expected results and Milestones

Atmospheric dust measurements of the 2012 ice core at Colle del Lys; new ice core drilling at Colle del Lys, planning of the next Himalaya-Karakoram ice core drilling activities and exploration of the logistical possibilities for the South Gasherbrum (Karakoram) glacier. Development of a measurement system for the optical properties of mineral dust. Reconstruction of the mineral dust record from the 2012 Colle del Lys ice core and reconstruction of the staked dust curve, from about 1930. Preliminary dating of the dust curve also by density firn/ice modelling. Geophysical measurements (radar) of the Baltoro Glacier (Pakistani Karakoram) and site selection for the 2014 ice drilling activities in the Gasherbrum I area, with reconstruction of the bedrock topography and presence of submerged crevasses. If possible, reconstruction of the radar stratigraphy of the selected drilling site. Ice core drilling until bedrock of the Lys Glacier for extending the climate records, using the 8 cm diameter drilling system from IceField©Canada (EvK2-CNR), that allows to reach a 250 m depth. In collaboration with the Physics Dept. of the University of Milano, development of a measurement system to define the optical properties of the mineral dust. A new light-weight auto-inflatable tent will be developed in collaboration with the Physics Dept. of the University of Milano, for use in cold and remote areas such as the Karakoram or the Himalaya mountains. Lab tests will done at EuroCold UNIMIB and at Colle del Lys (Valle d'Aosta).

2. Deliverables expected for the reference period

D1.4.2: Report on measurement activities; data transmission to the archives and the General Portal.

D1.4.3: Report on technological developments.

Deliverable D.1.4.4, originally planned for this WP, was joined with WP1.6.

3. Activities which have been actually conducted during the reference period

3.1 Research activities

Mineral dust at Colle del Lys (Monte Rosa, Italy)

The mineral dust concentration in the first 20 m of the Colle del Lys ice core, drilled in 2012, was investigated (CdL2012). An important result is related to the observation of a strong seasonality, which allows to improve the dating of the entire ice core and to provide a more reliable correlation with the already-existing mineral dust records from the same site. The 400 ice samples extracted from the core were characterised by a background value of mineral dust concentration ranging between 10-50 ppb, but reaching values of 3 ppm for concentrated spikes. Very high concentration events, reaching tents of ppm were observed. These high-concentration events are clearly visible at the ice core surface due to the red-yellow-brownish colour dust. Low concentration periods were associated to the winter seasons, while higher mineral dust concentrations were related to spring-summer periods when the occurrence of mineral dust transport events from North Africa to the Alpine area is more likely (Maggi et al., 2006). Figure 1 shows the mineral dust record within the first 20 m of CdL2012 ice core. A provisional dating is provided together with the annual counts of the number of particles (N/mL - in black) and in mass concentration (ppb) in red, both obtained by Beckmann-Coulter 3 © instrument. The aerosol mass was calculated by assuming a spherical shape of the dust particles and a 2.6 g/cm^3 mean mineral density (Delmonte et al. 2002; Maggi et al., 2006). The light-brown vertical lines in figure 1 denote the occurrence of the mineral dust layers observed in the ice core (because of the very high dust concentrations observed during these events, the related data were not plotted to ensure plot readability).

Scanning Electronic Microscope (SEM) observations show the presence in some samples of pollen remains, which will be studied to facilitate the attribution of the source regions of the detected mineral dust transport events.

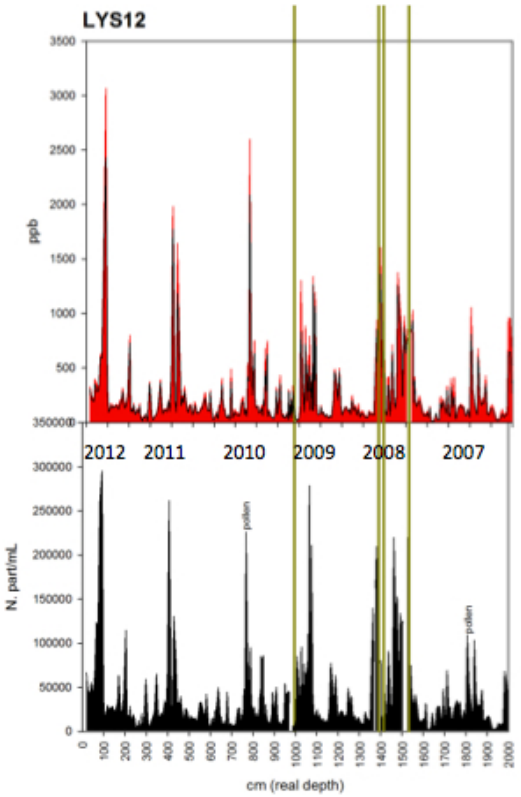

Fig 1. The first 20 m of mineral dust record of CdL2012. The upper plot reports the mineral dust concentration record (expressed as ppb), while the bottom plot reports the same information expressed as number of particles per liter.

A goal of this study is to characterise/identify the origin of mineral dust found in the ice: Saharan dust events, volcanic ash such as the Icelandic Eyjafjallajökull eruption occurred in March 2010, other transport events related with local or long-range emissions. The characterization of those events is carried out by the elemental analysis of the mineral particles, achieved using Instrumental Neutron Activation Analysis (INAA) followed by gamma spectroscopy measurements. These analyses were carried out at the TRIGA nuclear reactor facility in Pavia and at the radioactivity laboratory in Milano-Bicocca University.

Ice core drilling in the Leupa ice cave (Mount. Canin, Friuli Venezia Giulia, Italy)

The Department of Mathematics and Geosciences of the University of Trieste (DMG), the National Research Council of Italy (CNR, Department of Earth System Sciences and Environmental Technologies – ISMAR, Trieste), the University of Milano Bicocca (UMB), the University of Insubria (UI), the Unione Meteorologica del Friuli Venezia Giulia (UMFVG) and the Parco Naturale Regionale delle Prealpi Giulie (PNRPA) are involved in the project FRA 2012 (Finanziamento di Ateneo per progetti di ricerca scientifica) MonICa (MONitoring of Ice within the Caves) (Coordinator Emanuele Forte, University of Trieste). The aim of the project is to characterise the permanent ice deposits located in the underground karstic environment of the Eastern Alps.

On 30 September and 1-2 October 2013, in the framework of the MonICa project the main part of the planned fieldwork was realized in a cave of the Canin Massif, where a permanent ice deposit is located. This massif is mainly composed of dolomite and limestone of the Norian-Rhaetian platform (Dachstein limestones, Dolomia Principale) and a very developed network of cavities is present. A 7.8 m long ice core was extracted, using the ice core driller of

UMB developed/purchases in the framework of NextData. As soon the ice cores have been extracted, they were transported to the EUROCOLD Laboratory in Milan. The choice of the place where to extract the ice core was defined thanks to several GPR surveys performed by the Institutions involved in the MonICa project at the surface of the ice deposit. This allowed to visualize and avoid debris and boulder in the ice deposit, thus avoiding any possible damage of the ice driller tip. This is the longest core ever extracted in the Italian Alps from ice caves.

Analysis of pollen records from natural archives and archaeological deposits within the Project NextData: climate and vegetation over the last 3,000 years in northern Italy.

With the aim of creating an archive of palynological data for northern Italy over the last 3,000 years, we carried out a survey to identify already existing records. This led to the individuation of 61 published palynological stratigraphic successions from limnic/wet environment that (partially or entirely) cover the period of investigation The detected palynological records were critically analyzed, with a specific attention for the quality of the chronology - i.e. the number of absolute datings associated with the records. Basing on the records characterised by a good dating (three or more absolute dates), we started to digitalise the numerical data (pollen percentages) published only in graphical format, in order to obtain a base for further graphical and statistical elaboration.

In parallel with the acquisition of published data, which were integrated with the data owned by CNR-IDPA, we also worked to plan and organize the database that will allow the management (storing and processing) of these data records. Thanks to the analysis of the already existing pollen databases - such as the Global Pollen Database, The North American Pollen Database and the European Pollen Database - and considering the specific requirements of the NextData Project, we developed a work plan which will be discussed with the other members of the research team active at the University of Milan-Bicocca.
Moreover, with the aim to identify the most appropriate strategy/ies for the future elaboration of the collected palynological data, we studied different statistical functions to transfer the palynological data to paleoclimatic values, such as the Probability Density Function (PDF), the Modern Analogue Technique (MAT), and the Weighted Average (WA).

Application of a minimal glacier model: investigation of the length variations of the Careser Glacier (Ortles-Cevedale, Italy)

The behaviour of a valley glacier is determined by the sum of accumulation and ablation, which determine the glacier mass balance. These processes depend on several factor: climatic condition, topographic setting, geographic position and ice mechanics.
Mathematical models try to translate this complex situation into a simple description, based on the laws of physics, that represents the theoretical framework for numerical algorithms. An especially simple model is called the “Minimal Glacier Model” (Oerlemans, 2011), often used to investigate the overall dynamics of glaciers. This class of models does not explicitly describe space-dependent quantities such as ice thickness, basal water pressure, sliding velocity and others. A diagnostic relationship between the glacier length L and the average glacier thickness h, based on the assumption of perfect plasticity, is adopted. Consequently, the only dynamical variable of the model is the glacier length L. The evolution of the glacier is calculated from an integrated continuity equation over the entire ice volume.
The Minimal Glacier Model was applied to the Careser Glacier (Ortles-Cevedale, Eastern Italian Alps), that is the residual accumulation area of a much wider glacier that, during the Little Ice Age, exhibited a well-developed valley tongue.

On the Careser, mass-balance and ELA (Equilibrium Line Altitude) measurements have been carried out since 1967 and the data series, the longest for the Italian Alps, extends to the present without interruption (Zanon, 1982; Carturan and Seppi, 2007; Carturan et al., 2009a). There are also several maps and studies on the cartography and geomorphology of this glacier (Carturan et al., 2013). As a consequence a DEMs (Digital Elevation Model) was drawn by using data collected by remote sensing techniques and by land surveys carried out from 1933 by different Institutions. Using DEMs, we reconstructed the evolution of polygon, contour map and dimension of the glacier, drawing the flow lines that follow the accumulation-ablation dynamics and to which we applied the minimal model.

Glacier snout variations respond to climatic fluctuations with a time delay from years to tens of years (Oerlemans, 2001). In minimal models, the input data sets are represented by the mass balance and the Equilibrium Line Altitude, which follow climatic oscillations.
Therefore, we related winter precipitation and summer temperature to the mass balance and Equilibrium Line Altitude series, by using a bivariate fit as a transfer function of climate forcing on glacier behaviour. We used the ERA-Interim data set, a global atmospheric reanalysis produced by the European Centre for Medium-Range Weather Forecast (ECMWF) as climate input data.

To study the dependence between climatic variables and glacier snout fluctuations (Bonanno et al., 2013), and based on the results of correlation analyses, the following parameters were identified:

- Winter precipitation(from December to March);
- Summer temperature(from June to September).

A good match exists between length variations obtained with mass balance and ELA with that obtained by using climate forcing (ERA Interim data). As shown by figure 2, only in 1965-1980 the model results fit well with measured data, while since 1980, the model results showed a faster length decrease than the observations.

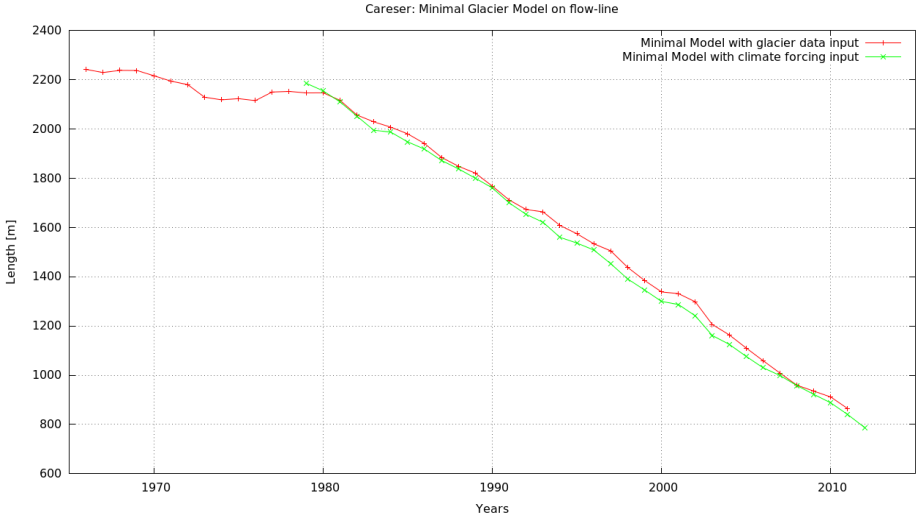

Fig. 2. Comparison between model outputs using measured ELA and mass balance data (red curve) and using reconstructed ELA and mass balance values from climatic parameters.

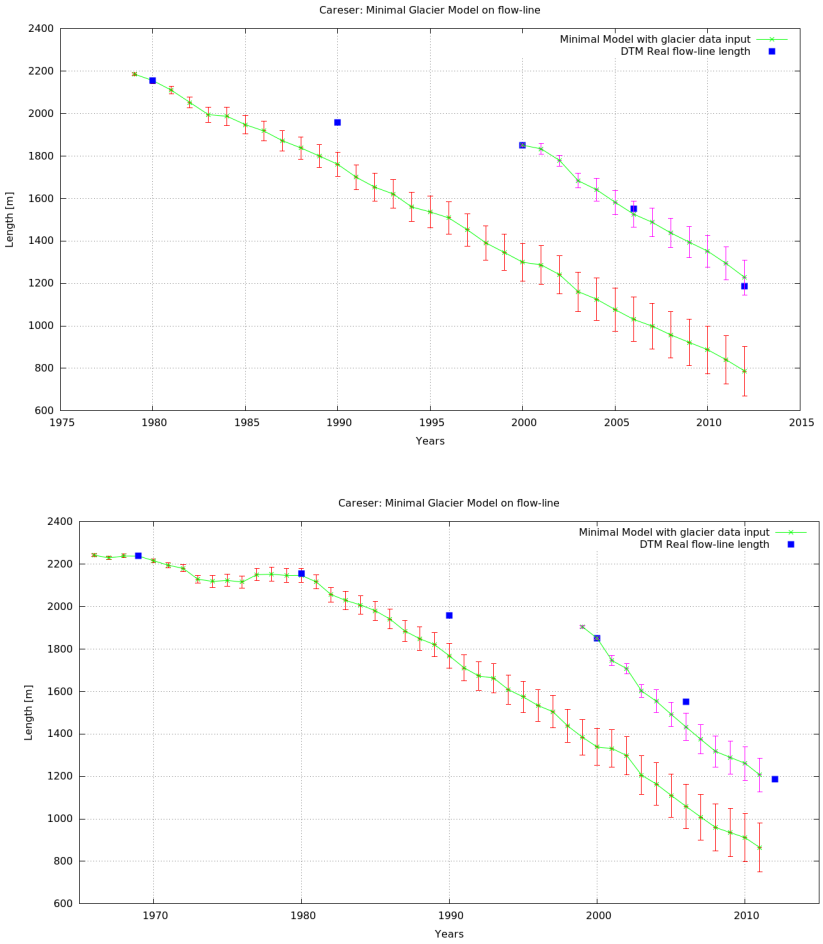

Fig. 3. Results of the different runs of the Minimal Glacier Model, compared with the measured length variation (from DTM): (upper panel) mass balance and ELA input, period [1967 – 2012]; (lower panel) mass balance and ELA parameterized through the climate forcing input, period [1979 – 2012]. In each panel, the upper curve represents the run of the minimal model starting from initial conditions in 2000.

From 1981, the Accumulation Area Ratio of the Careser glacier was always zero or near-zero. This condition stopped the continuous flow of ice/material and the standard dynamics of the glacier since the end of the 80's.

In the last 20 years, the Careser glacier showed a passive, local melt-driven retreat everywhere, and the disappearance of the upper part and the mid-west region. This condition brings the mid-west mass area in a complete ablation phase: the rapid mass loss and fragmentation of this region generate a significant problem in mass balance.
The normal glacier mass flow is characterized by two different components: the fluid dynamics of ice from the high accumulation area to the below ablation region and the thermodynamic melting caused by the positive balance of heat on the surface. The balance between these processes generates advance or retreat of the glacier, following the climate forcing. On the Careser glacier, it is evident the disappearance of the fluid-dynamical contribution since the early '80s, with increasing thermodynamic-driven melting.

The break of the accumulation-ablation dynamics explains the reduced speed of front retreat, compared to model results for the period 1980 - 2000. These processes created a peninsula of stationary ice, included and protected by two elevation drops, upwards and downwards. This peninsula is a flat strip of land of about 300 m x 800 m, with a slight rise on the ridge.

In that area it is clear that the fluid dynamics of the glacier stopped and the only accumulation was due to drifted ice, coupled with the purely local thermodynamic melting. This situation masks the actual length variations of the glacier front.

At the beginning of the '80s, the minimal model was not able to reproduce the real position of the glacier front, because the thickness of the ice peninsula was sufficient to slow down the length variations. This condition persisted up to year 2000, when the diagram shows a change in the retreat. After that period, the thickness of the ice peninsula became slim, exceeding a threshold from which the glacier disappeared.

The ice dynamic collapse, the null value of the accumulation rate and the currently climate warming exacerbate the decrease of the volume, area and thickness of this glacier. Only a prolonged lowering of the ELA by at least 400 m, from about the present 3500 to the middle of the glacier, would stop this glacier to decay.

References

BONANNO R., RONCHI C., CAGNAZZI B. and PROVENZALE A. (2013): Glacier response to current climate change and future scenarios in the north western Italian Alps. *Reg. Environ. Change.* v.13, n.4.

CARTURAN L. and Seppi R. (2007): Recent mass balance results and morphological evolution of Careser Glacier (Central Alps). *Geogr. Fìs. Din. Quat.*, 30(1), 33–42.

CARTURAN L., DALLA FONTANA G. and CAZORZI F. (2009a): The mass balance of La Mare Glacier (Ortles-Cevedale, Italian Alps) from 2003 to 2008. In *Epitome: Geoitalia 2009, Settimo Forum Italia*no *di Scienze della Terra*, 9–11 September 2009, Rimini, Italy, Vol. 3. Federazione Italiana di Scienze della Terra, 298.

CARTURAN L., BARONI C., BECKER M., BELLIN A., CAINELLI O., CARTON A., CASAROTTO C., DALLA FONTANA G., GODIO A., MARTINELLI T., SALVATORE M.C. and SEPPI R. (2013): Decay of a long-term monitored glacier: Careser Glacier (Ortles-Cevedale, European Alps). The Cryosphere., 7, 1819-1838,2013.

DELMONTE, B., PETIT, J.R. and MAGGI, V., 2002: LGM-Holocene changes and Holocene millennial scale oscillations of dust particles in the EPICA Dome C ice core, East Antarctica. *Annals of Glaciology*, 35(1): 306-312.

MAGGI, V., VILLA, S., FINIZIO, A., DELMONTE, B., CASATI, P. and MARINO, F., 2006: Variability of anthropogenic and natural compounds in high altitude-high accumulation alpine glaciers *Hydrobiologia* 562, 43-56.

OERLEMANS J. (2001): Glaciers and climate change. *Balkema Publishers,*Lisse.

OERLEMANS J. (2011): Minimal glacier models. *Second print. Igitur, Utrecht Publishing & Archiving Services, Universiteit sbibliotheek Utrecht*. ISBN 978-90-6701-022-1.

ZANON G. (1982): Recent glaciological research in the Ortles- Cevedale region (Italian Alps). *Geogr. Fìs. Din. Quat.*, 5(1), 75–81, 1982.

3.2 Applications; technological and computational aspects

Collaboration between UNIMIB-DISAT and UNIMI-Physics for a continuous measurement system for the optical properties of mineral dust trapped in glacier ice and snow. In the first year a group of standards and samples were measured to define the size distribution, concentration and scattering properties.

Collaboration between UNIMIB-DISAT and UNIMI-Physics for the development of a new inflatable tent for polar and high-mountain climatic conditions. Tests in Milano, at the EuroCold Laboratory, and at the Colle del Lys, indicated that the tent appear to be appropriate for use during remote camp in high mountain regions (e.g. Karakorum and Himalaya).

3.3 Formation

First year of the doctorate of Massimiliano Moretti, devoted to the development of mass balance glacier modelling for future scenarios. In the first year, a Careser Glacier minimal model was developed to reconstruct the past 40 years of mass balance and compare them with field measurements.

V. MAGGI: Sources and transport of atmospheric mineral dust: examples from ice cores. *Alpine Summer Schoo*l, Valsavarenche, Valle d'Aosta (Italy), 20 June 2013.

V. MAGGI: Palaeoclimatic and climatic effects of mineral dust: an ice core perspective. *Alpine Summer School*, Valsavarenche, Valle d'Aosta (Italy), 21 June 2013.

3.4 Dissemination

V. MAGGI: Mid-latitude ice core records from high mountains. *High Summit - International Conference on Mountains and Climate Change*, Lecco, 23-25 October 2013.

4. Results obtained during the reference period

4.1 Specific results (Data libraries, Measurements, Numerical simulations, etc)

All the data and the model results are stored in the NextData Database, managed by WP 2.3

4.2 Publications

Two paper in preparation, one (first name Moretti) on the Careser Glacier Minimal Model results, and the second (first name Maggi) on the mineral dust record from Colle del Lys.

4.3 Availability of data and model outputs (format, type of library, etc)

See the WP 2.3

4.3 Completed Deliverables

All.

5. Comment on differences between expected activities/results/Deliverables and those which have been actually performed.

All the main activities planned for the second year were completed. The most important deviation was related to the impossibility to drill the Colle del Lys to a sufficient depth, owing to the harsh meteorological conditions and break-up of the ice core drilling system. Mass balance modelling for Alpine glaciers, not originally planned, was added. In particular, a Careser Glacier model was developed to reproduce the mass balance evolution since the '60s.

6. Expected activities for the following reference period

Based on the work already produced, during the third year of the NextData Project a paper will be submitted, including the main results of the application of the "Minimal Glacier Model" to the retreat of the Careser glacier (Ortles-Cevedale, North-East Alps). CMIP5 global climate models will be used to simulate glacier response based on different future climate scenarios. The Minimal Model will be applied to the Rutor glacier (Val d'Aosta), to be considered as a case study, to set-up a useful and adaptable tool for glacier forecast analysis. Furthermore, this work envisages the development of algorithms to transfer geospatial methods to the areas of interest, through GIS (Geographic Information System) software. A physical module will be produced with mathematical functions able to obtain the variation of the glacier thickness from a digital terrain model. A module for the application of the Minimal Glacier Model within GIS technology, to reconstruct the retreat of a glacier front, will be developed.